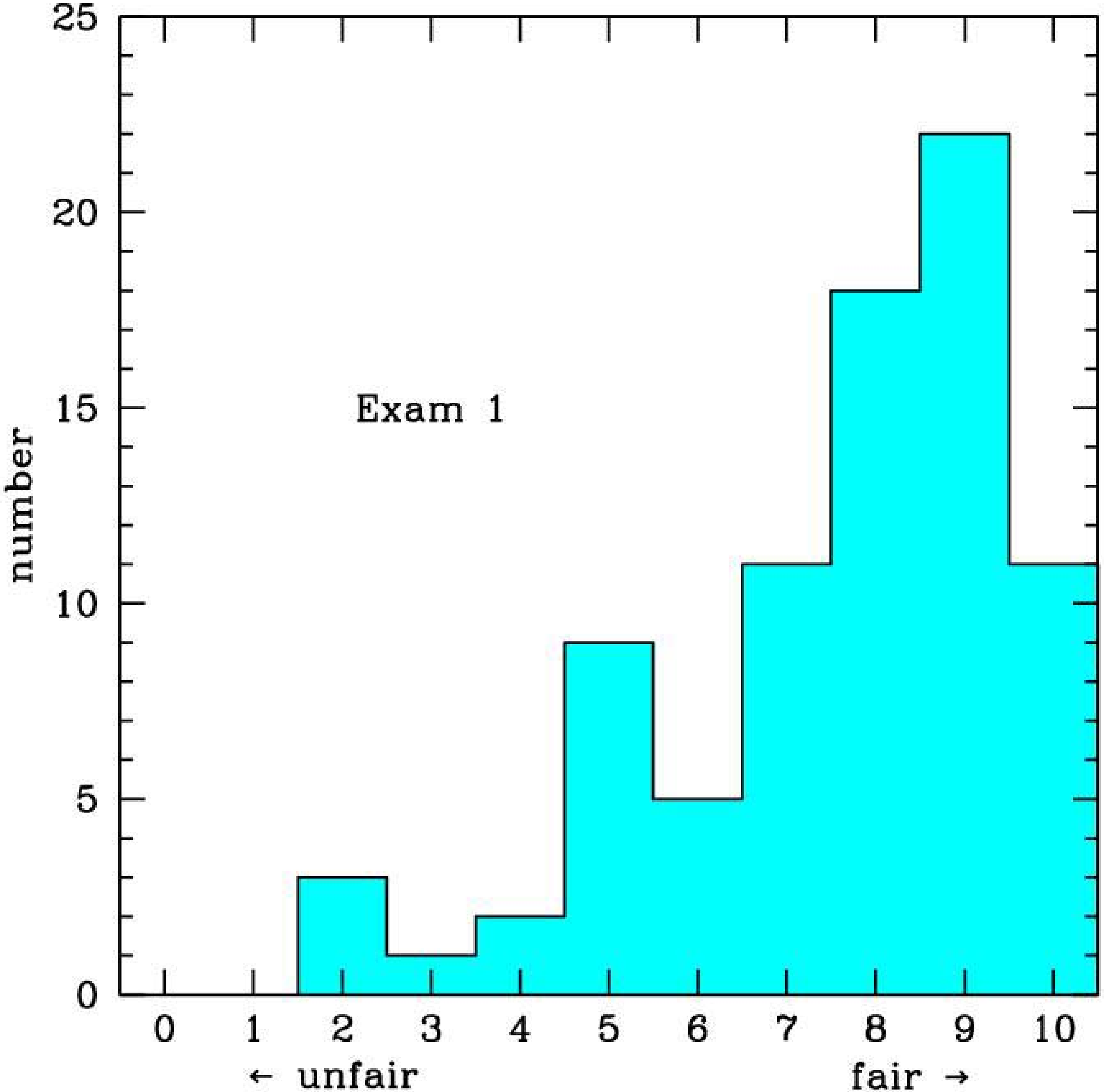
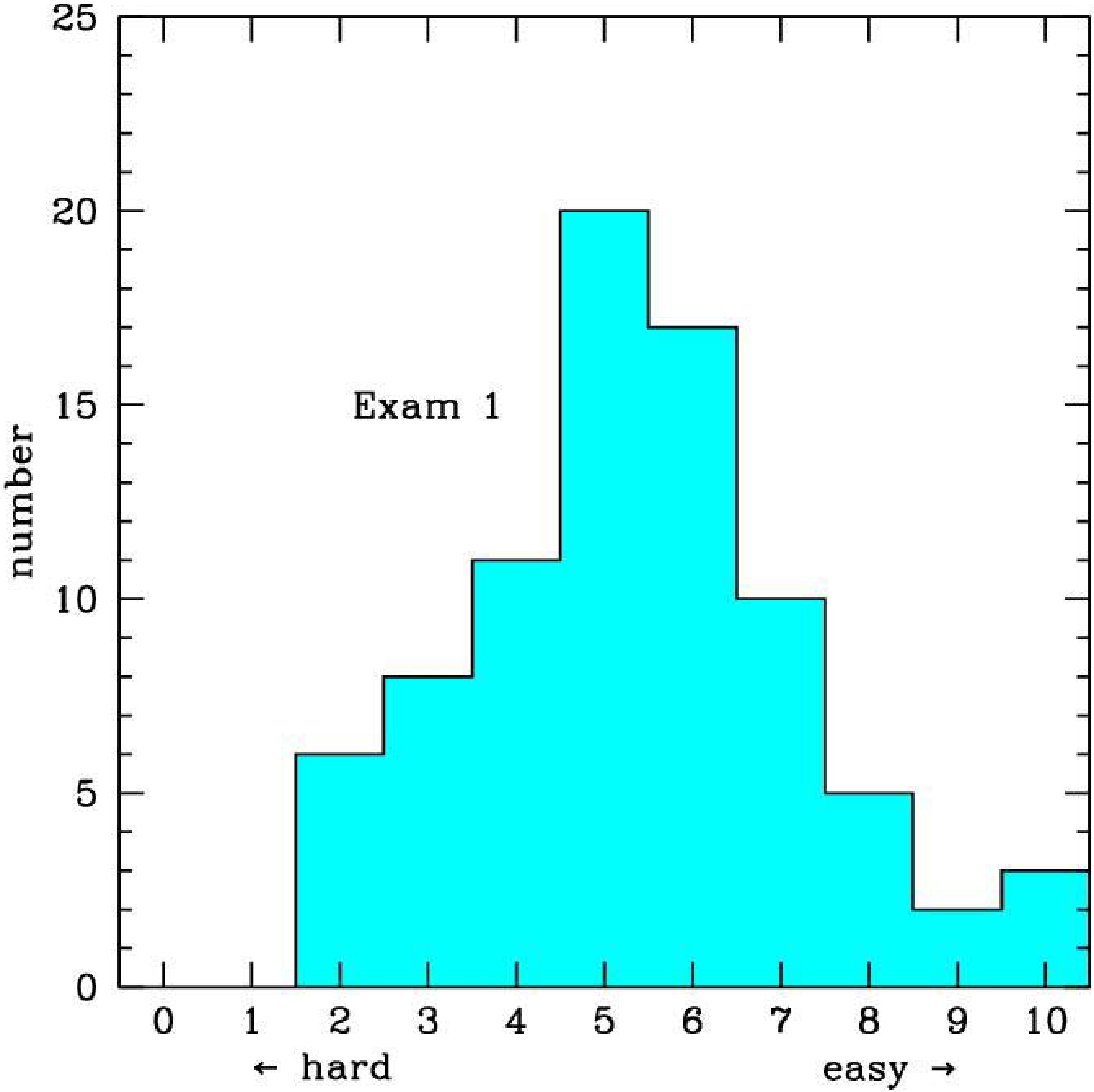
NS102 Lecture 8 April 27, 2004



25
20
15
10
5
0
number
Exam 1
0
1
2
3
4
5
6
7
8
9
10
← unfair
fair →



25
20
15
10
5
0
number
Exam 1
0
1
2
3
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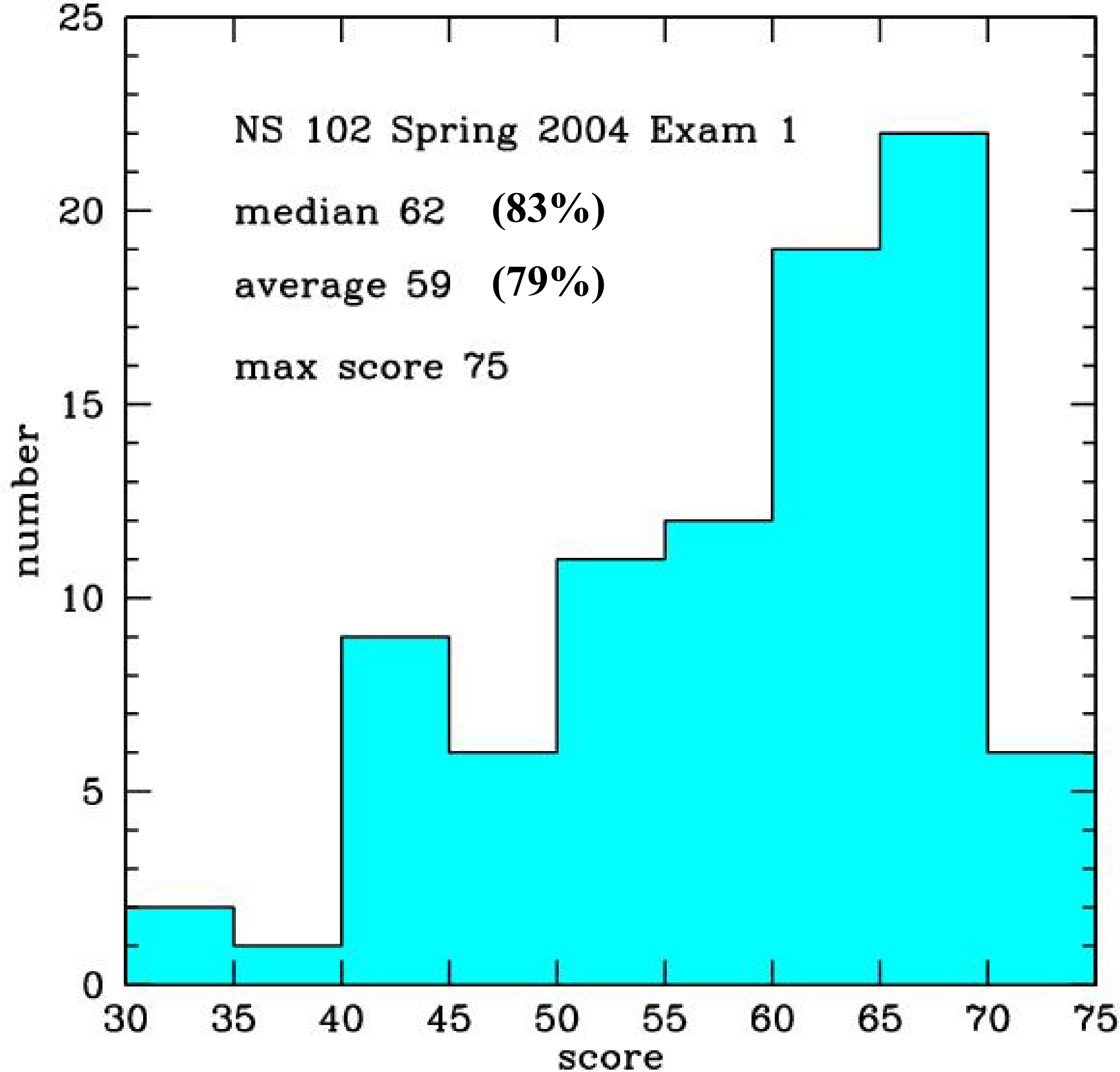
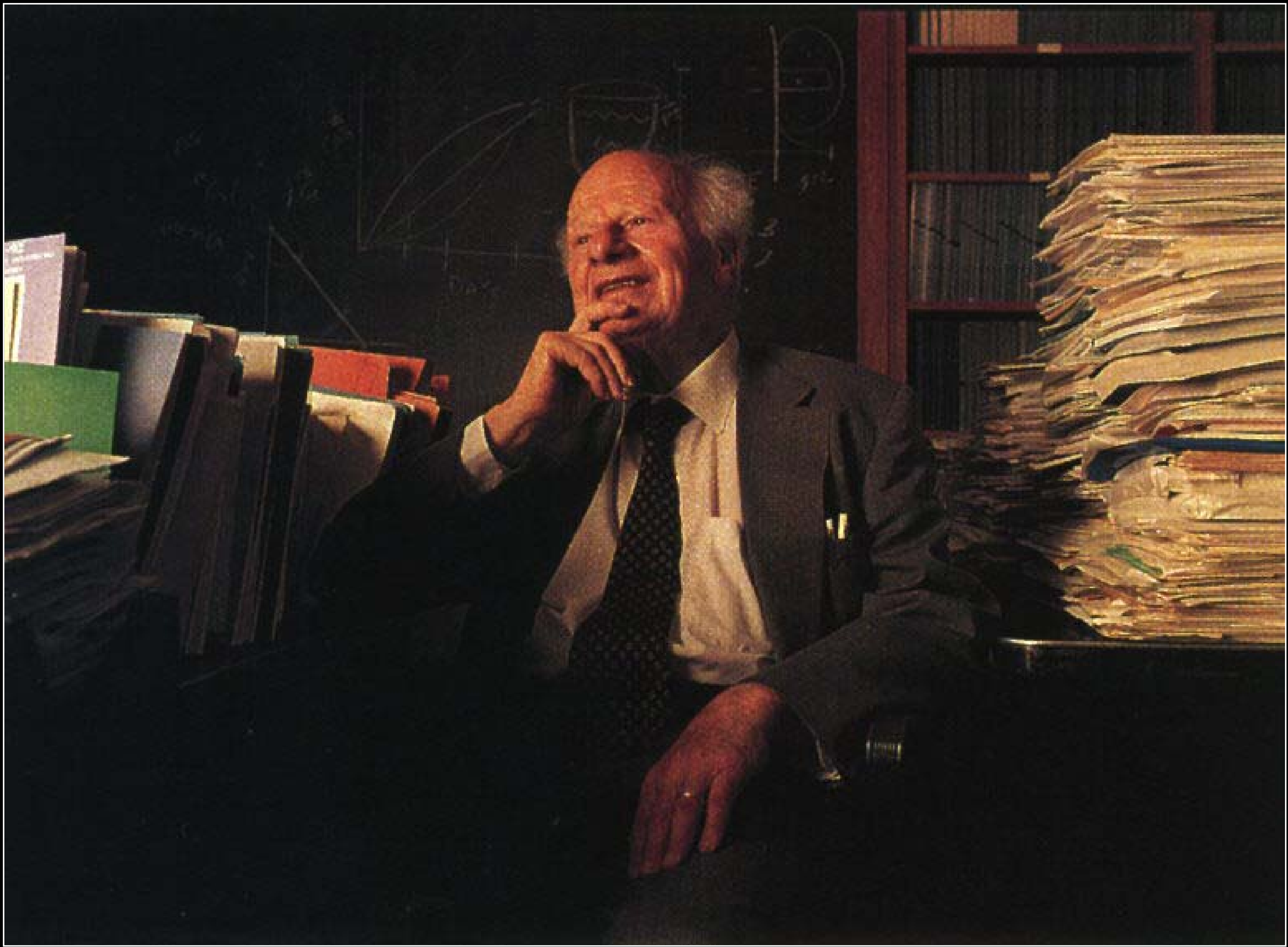
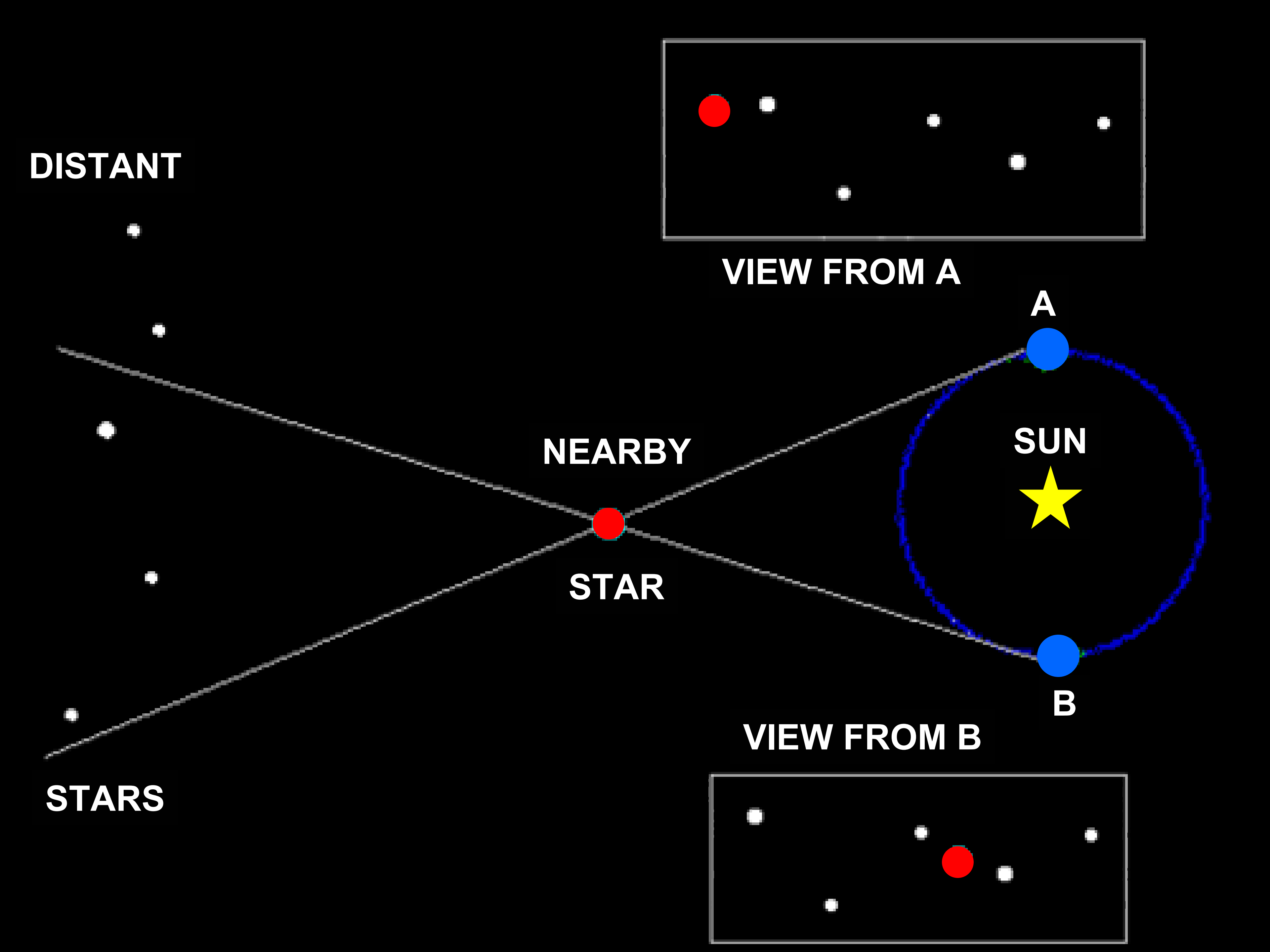
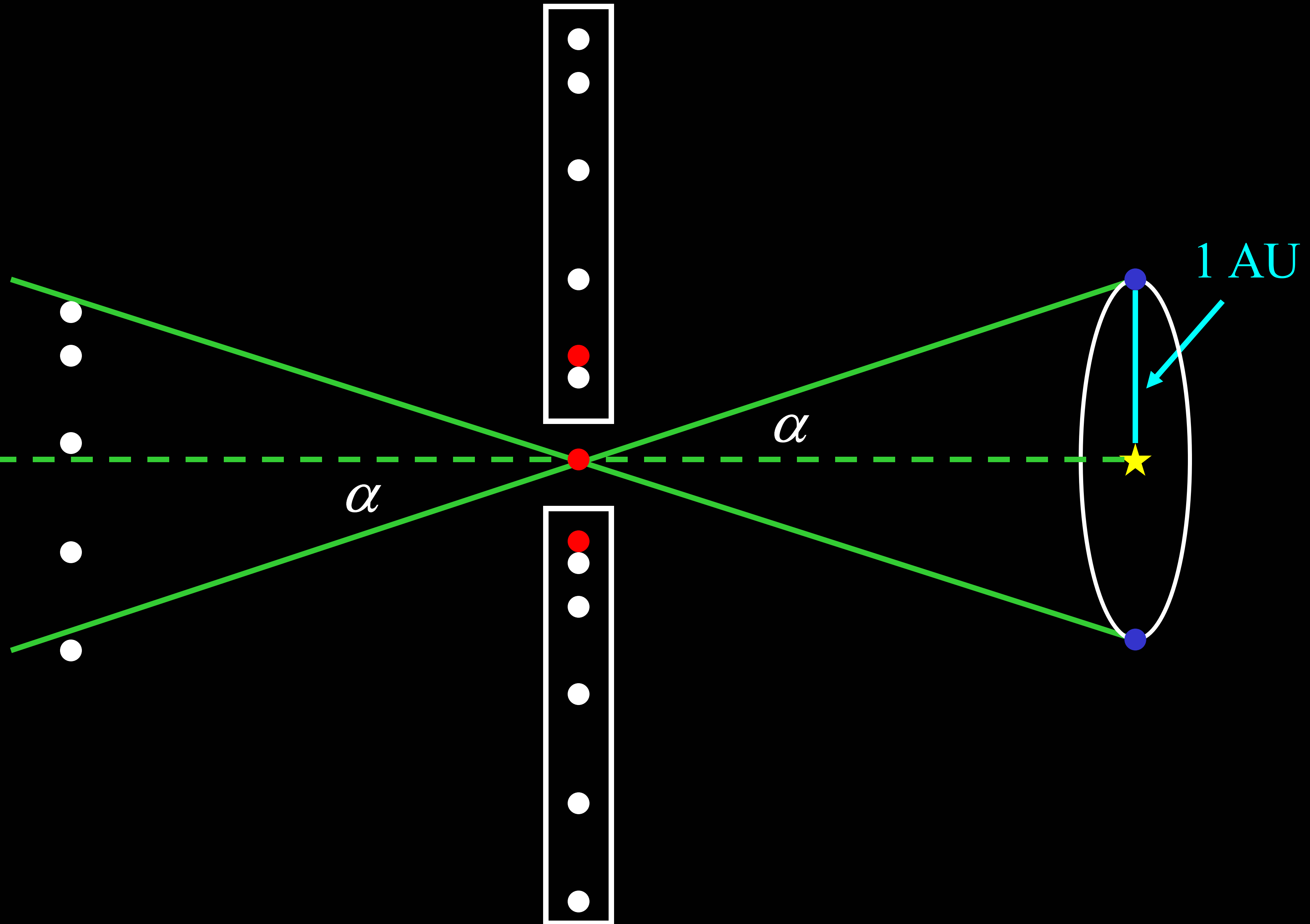
7
8
9
10
← hard
easy →


NS 102 Spring 2004 Exam 1
median 62 (83%)
average 59 (79%)
max score 75
number
score
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75

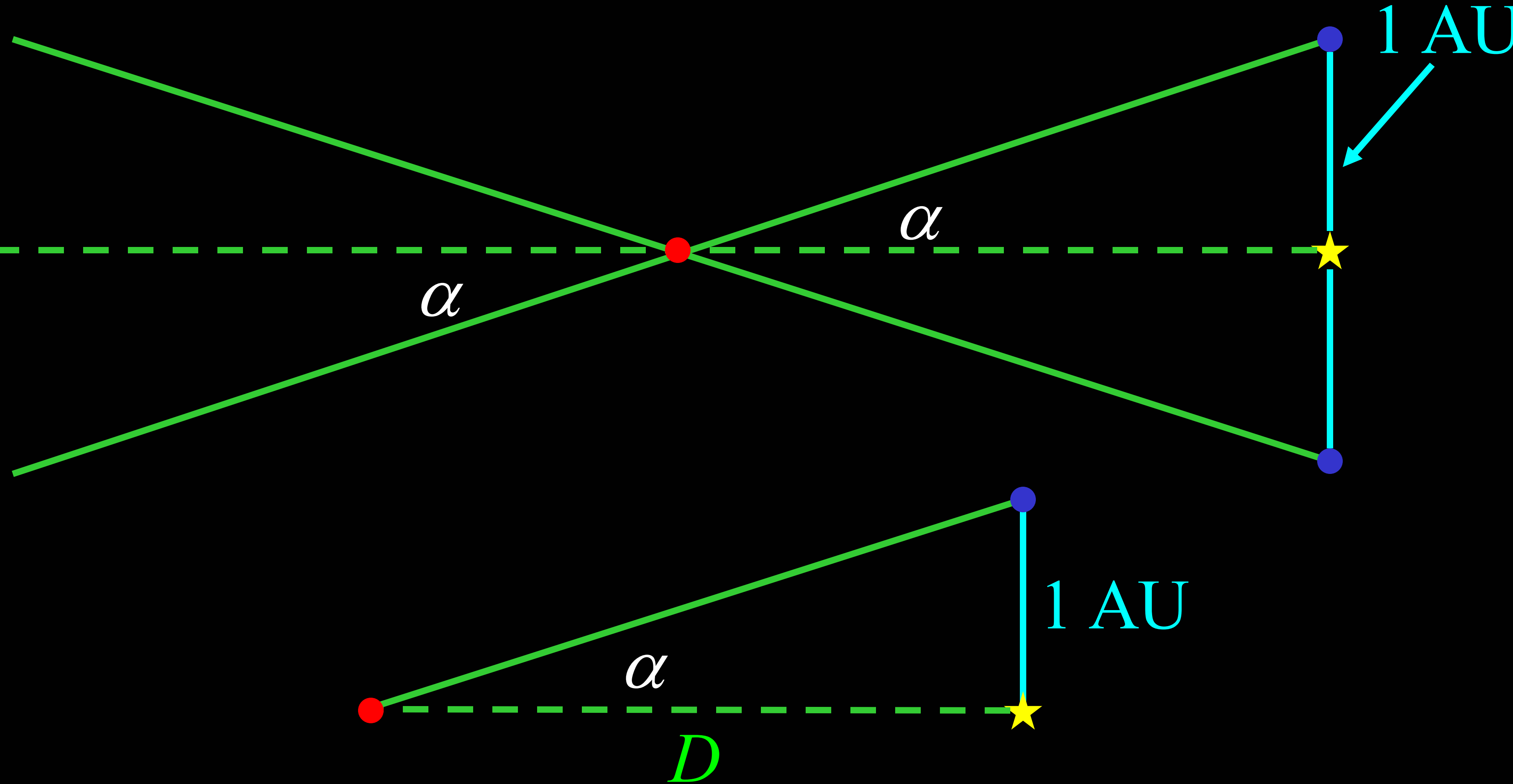
Why do the stars shine?



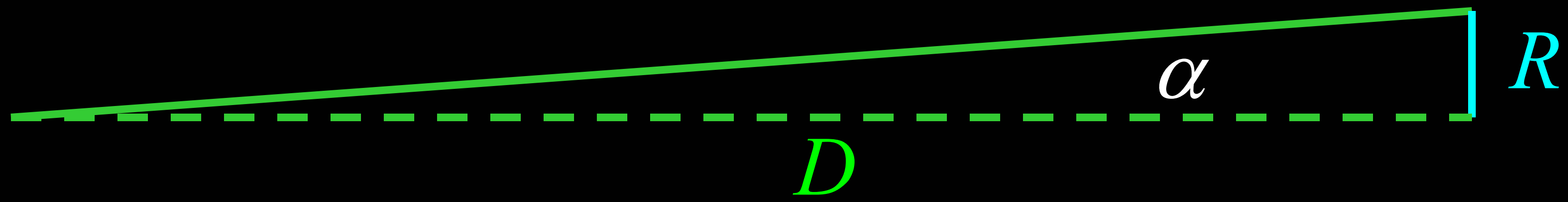

DISTANT
STARS
VIEW FROM A
A
NEARBY
STAR
SUN
B
VIEW FROM B



1 AU
α
α



$$\tan \alpha = \frac{1\ \mathrm{AU}}{D}$$



$$\tan\alpha = \frac{R}{D}$$

law of skinny triangles:

$$\tan\alpha = \sin\alpha = \alpha \quad \text{(in radians)}$$

$$\alpha \quad \text{(in radians)} = \frac{R}{D}$$

What's a radian?

$$2\pi \text{ radians} = 360 \text{ degrees}$$

$$1 \text{ radian} = \frac{360}{2\pi} \text{ degrees} = 60 \text{ degrees}$$

$$0.01 \cancel{\text{radians}} \times \frac{60 \text{ degrees}}{1 \cancel{\text{radian}}} = 0.6 \text{ degrees}$$

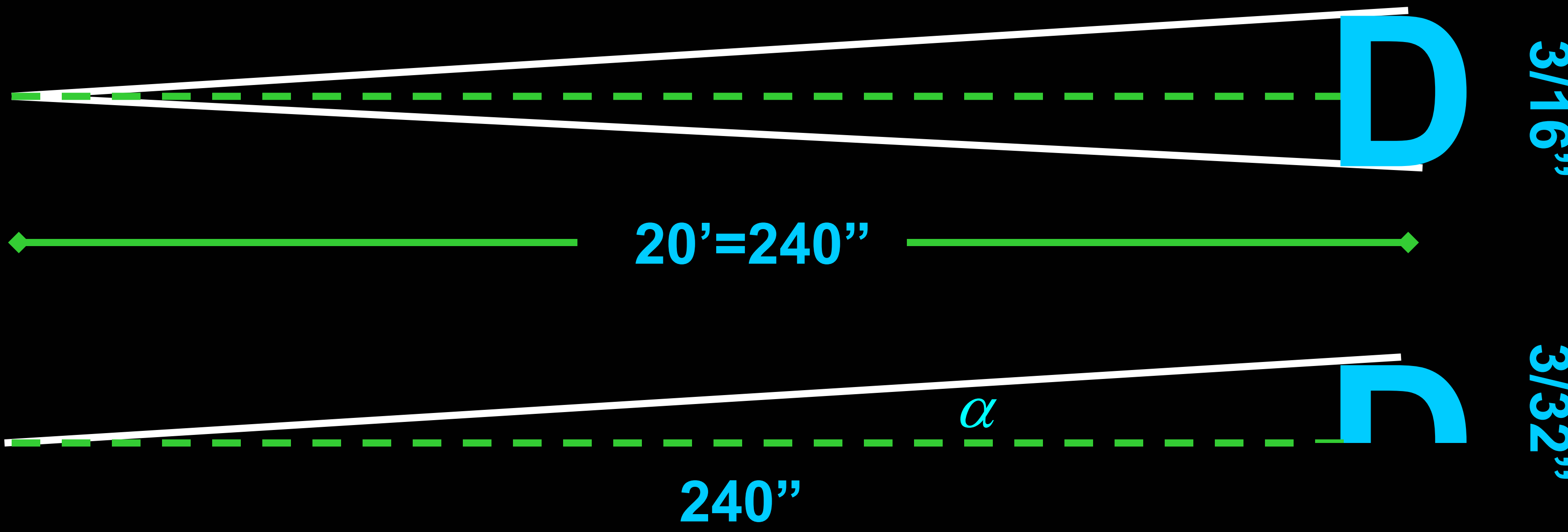
$$3 \cancel{\text{degrees}} \times \frac{1 \text{ radian}}{60 \cancel{\text{degrees}}} = 0.05 \text{ radians}$$

The skinny on traingles

α (degrees)	α(radians) = α (degrees) $\times \dfrac{2\pi}{360^\circ}$	$\tan\alpha = \alpha + \dfrac{\alpha^3}{3!} + \cdots$	$\sin\alpha = \alpha - \dfrac{\alpha^3}{3!} + \cdots$
3º	0.05236	0.05241	0.05234
10º	0.17453	0.17633	0.17365
30º	0.52360	0.57735	0.50000
100º	1.74533	0.98481	–5.67128

F	70
B C	60
P T E O	50
B Z F E D	40
O F C L T B	30
T E P O L F D Z	20
L P C T Z D B F E O	15
Z O E C F L D P B T	10
E T O L E B Z E F D C	7
B O F C P T E B L F B E Z C O P E	4

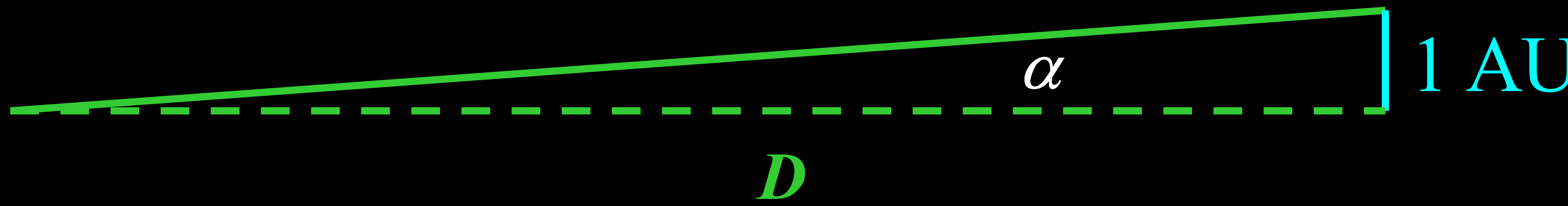
How good are your eyes?



$$\alpha = \frac{3}{32}\frac{1}{240} = 4\times 10^{-4}\ \cancel{\text{radians}} \times \frac{360\ \text{degrees}}{2\pi\ \cancel{\text{radians}}} = 0.02^{\circ}$$

$$\alpha = 0.02^{\circ} \times \frac{60\ \text{minutes}}{1\ \text{degree}} = 1'$$

D $= 2'$

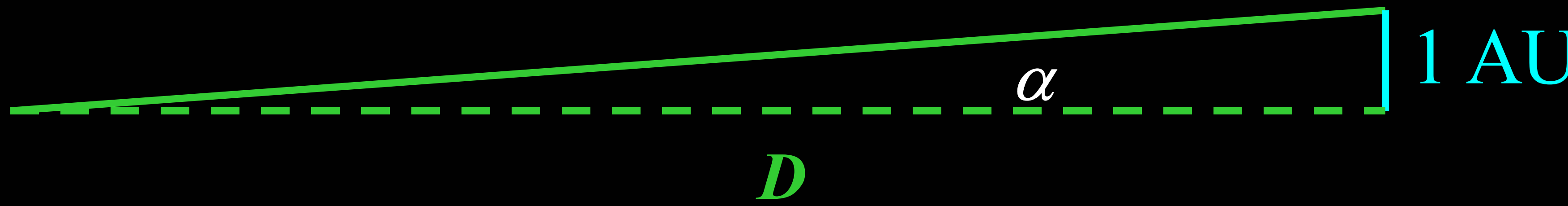


$$\alpha = \frac{1\ \mathrm{AU}}{D}\ \cancel{\text{radians}} \times \frac{60\ \text{degrees}}{\cancel{\text{radian}}}$$

$$\alpha = \frac{60\ \mathrm{AU}}{D}\ \cancel{\text{degrees}} \times \frac{60\ \text{minutes}}{\cancel{1\ \text{degree}}}$$

$$\alpha = \frac{3600\ \mathrm{AU}}{D}\ \cancel{\text{minutes}} \times \frac{60\ \text{seconds}}{\cancel{1\ \text{minute}}}$$

$$\alpha = \frac{206{,}264.8\ \mathrm{AU}}{D}\ \text{seconds}$$



$$\alpha = \frac{1\ \mathrm{AU}}{D} \quad \text{radians}$$

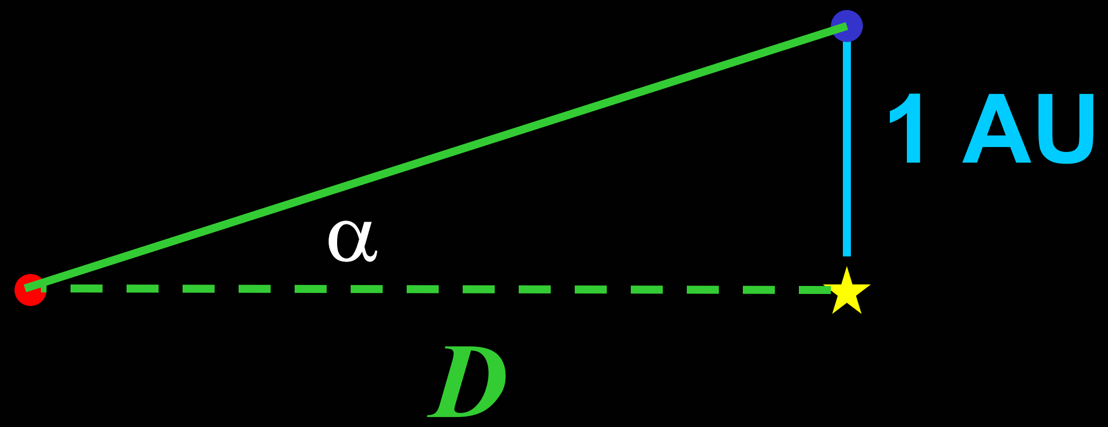
$$\alpha = \frac{206{,}264.8\ \mathrm{AU}}{D} \quad \text{seconds}$$

1 pc = 206,264.8 AU = 3.26 light years
= 10^{13} (10,000,000,000,000) miles

$$\alpha = \frac{\mathrm{pc}}{D} \quad \text{seconds} \qquad D = \frac{\text{second}}{\alpha} \quad \mathrm{pc}$$

$$\frac{D}{200{,}000\ \text{AU}} = \frac{\text{seconds}}{\text{parallax}}$$

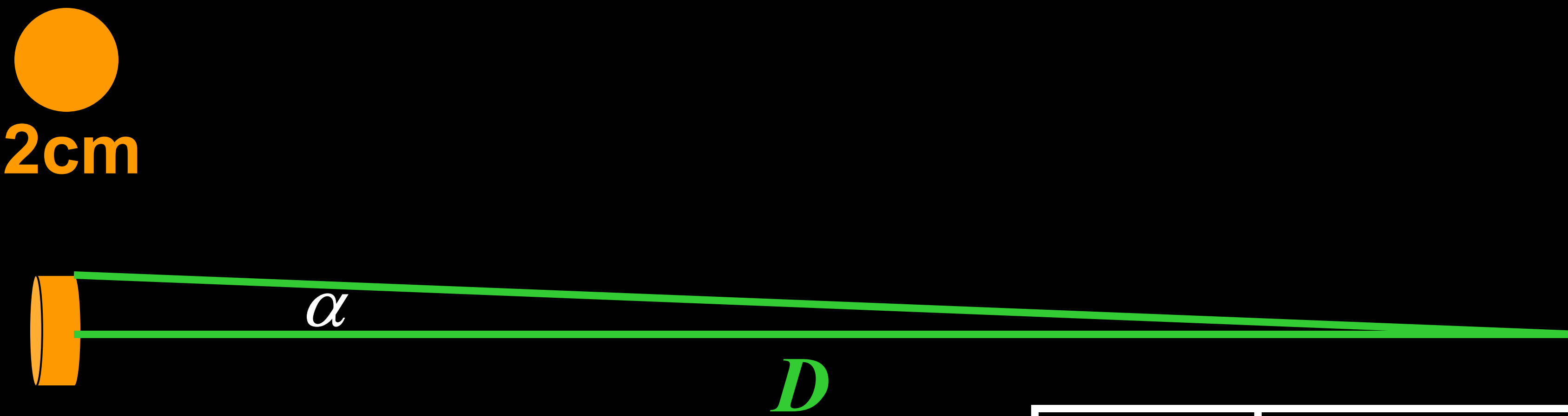
$$\frac{D}{\text{pc}} = \frac{\text{seconds}}{\text{parallax}}$$



$$\frac{D}{\text{pc}} = \frac{\text{seconds}}{\text{parallax}}$$

star	parallax ('')	distance (pc)
α Centauri	0.75	1.3
Barnard's star	0.5	2.0
Sirius	0.4	2.5
Altair	0.2	5.0

Let’s think for a second of arc



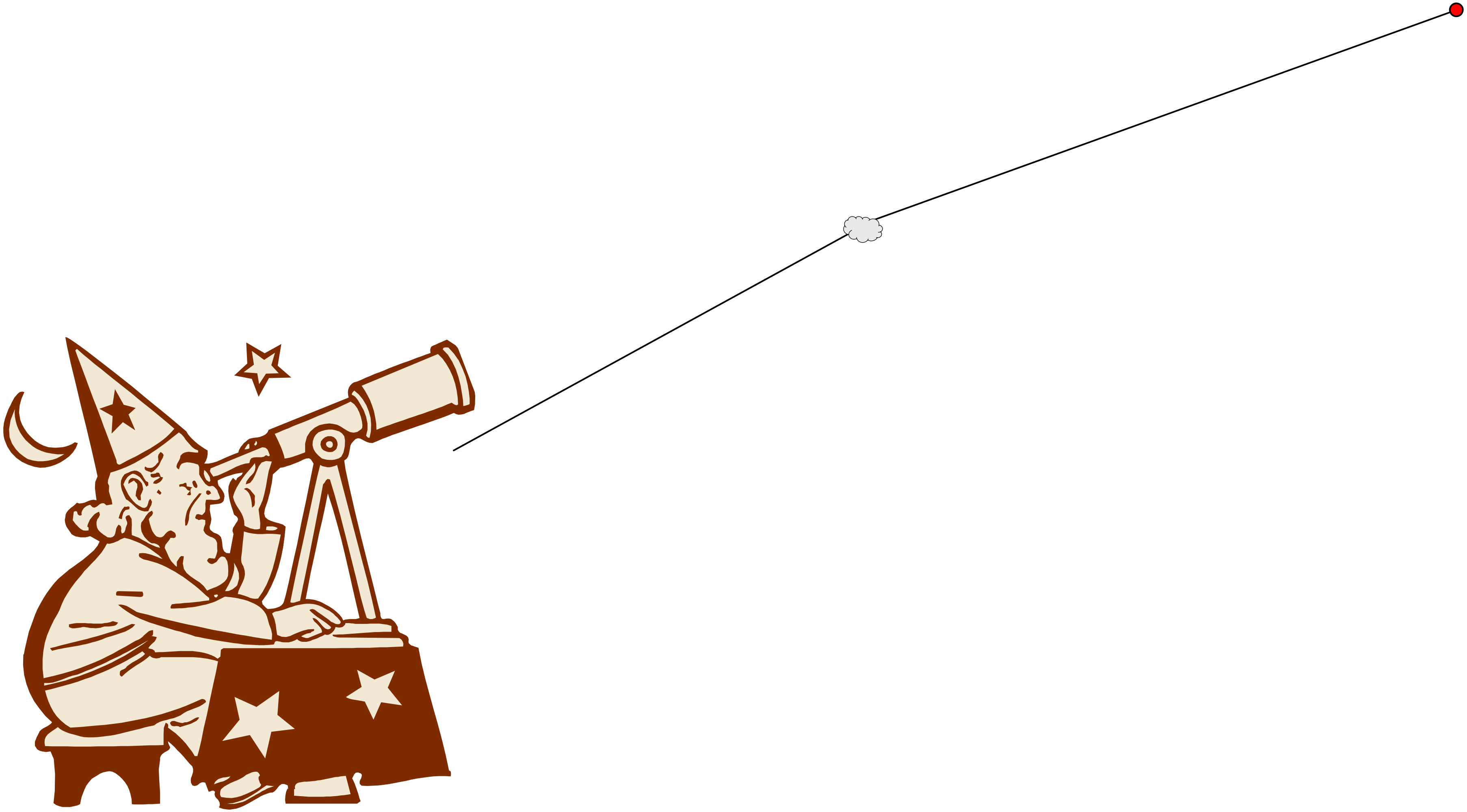
$$\alpha = \frac{1\ \text{cm}}{D}\ \text{radians}$$

$$\alpha = \frac{200{,}000\ \text{cm}}{D}\ \text{seconds}$$

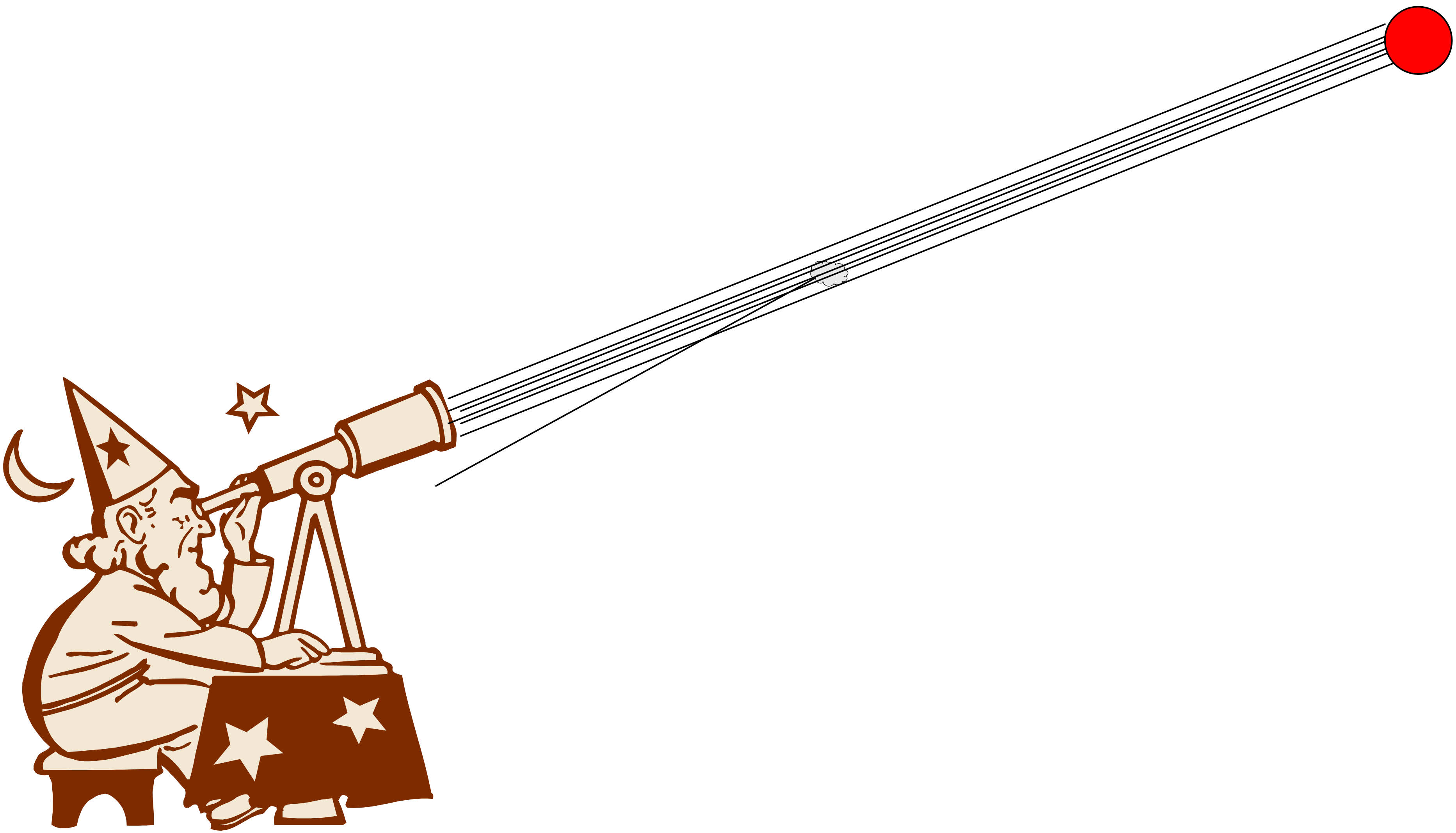
$$\alpha = \frac{2\ \text{km}}{D}\ \text{seconds}$$

α	D
4”	½ km
2”	1 km
1”	2 km
0.1”	20 km
0.01”	200 km
0”	infinity

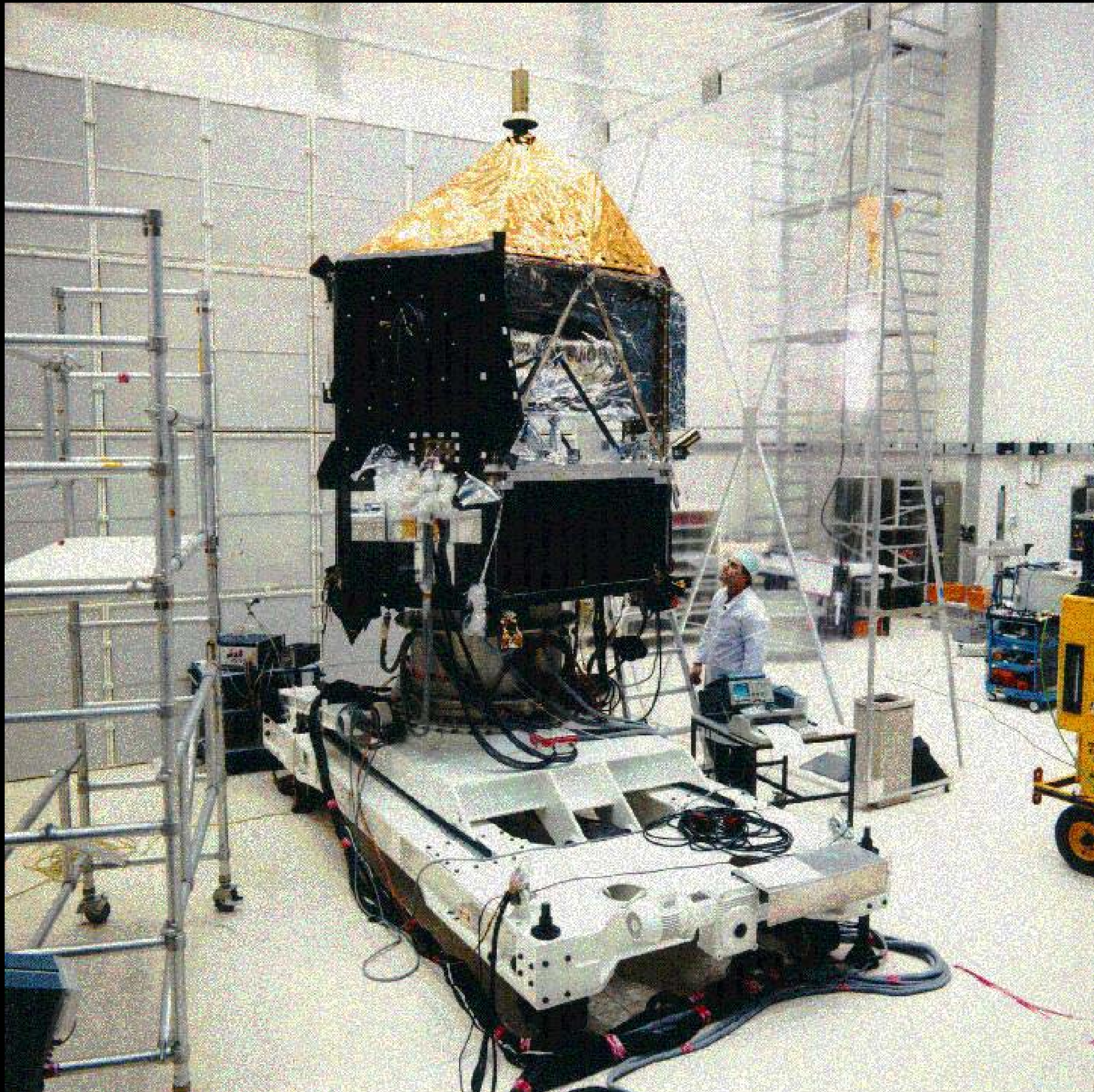
Twinkle, twinkle little star

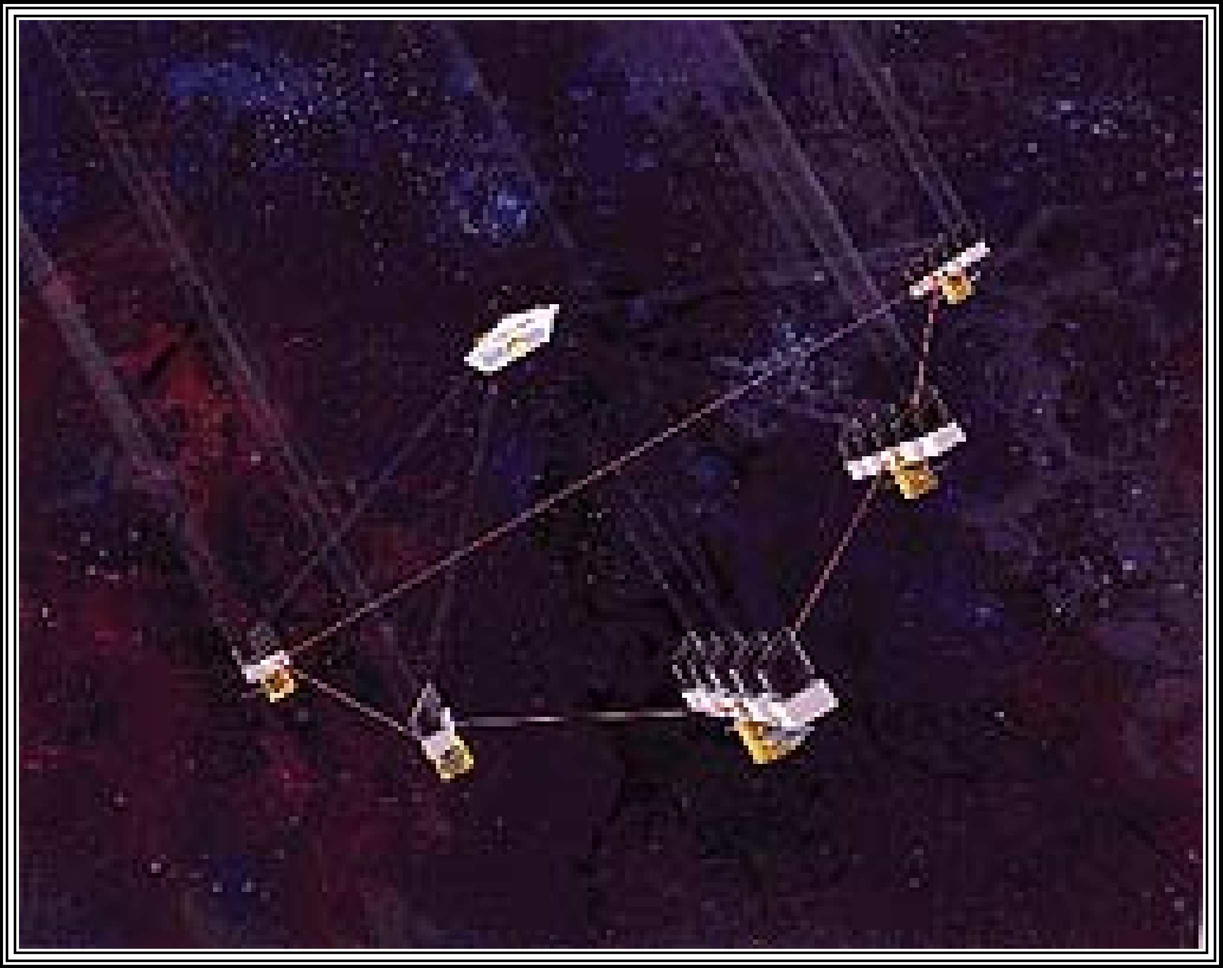


Twinkle, twinkle little star



Hipparcos



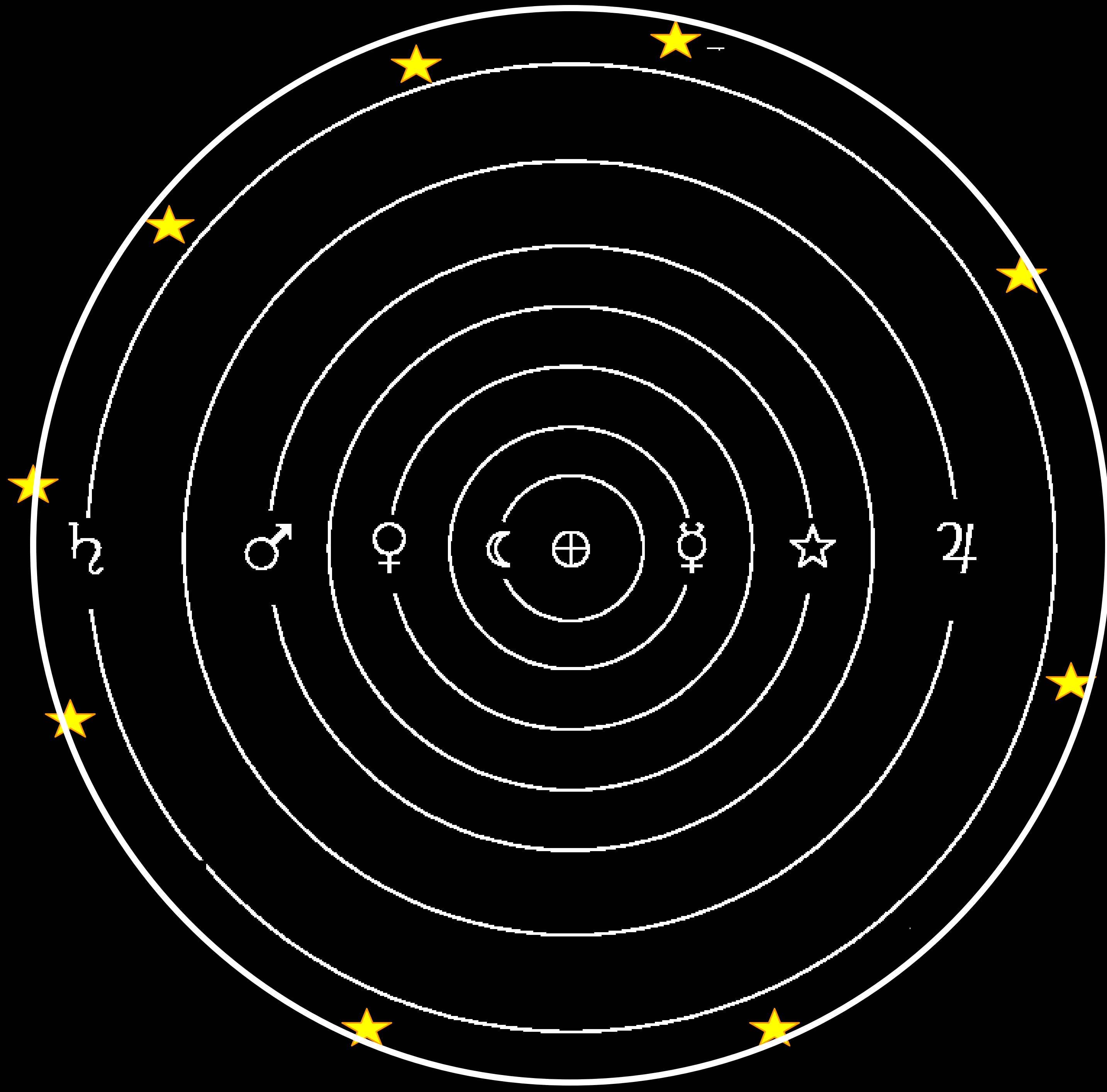


Planet Imager

Formation Flying

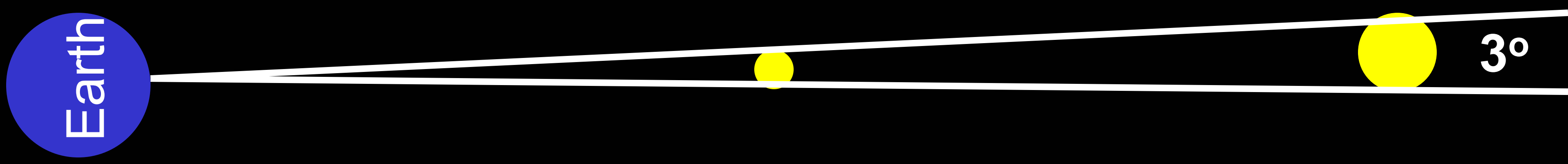
Launch: 2030

32 X 8 meter mirrors
Baseline = 6000 km

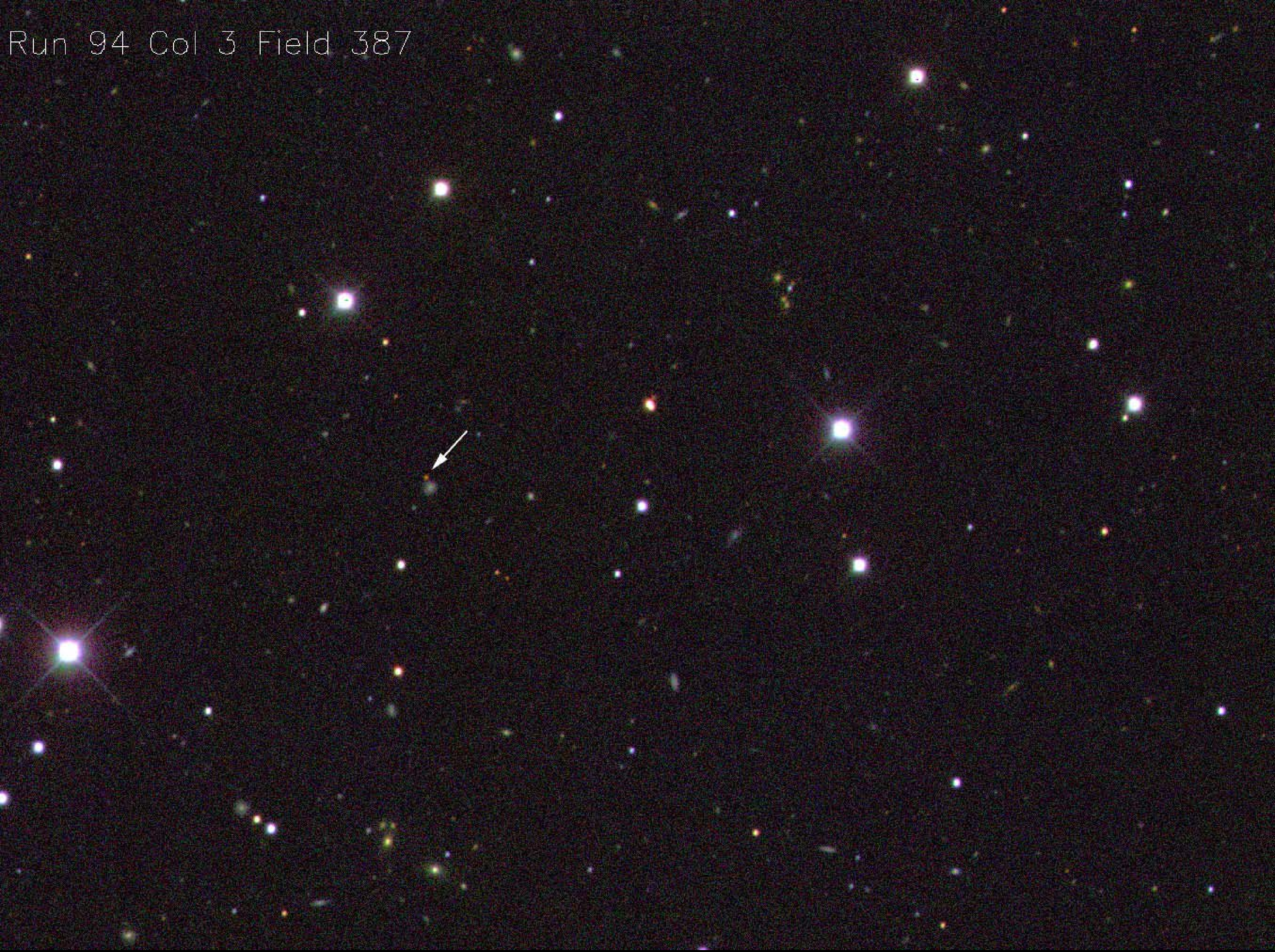


Planet	angular diameter (in minutes) Ptolemy	True
Mercury	2	0.01
Venus	3	0.5
Mars	1.5	0.15
Jupiter	2.5	0.4
Saturn	1.7	0.2
Bright stars	1.5	~0

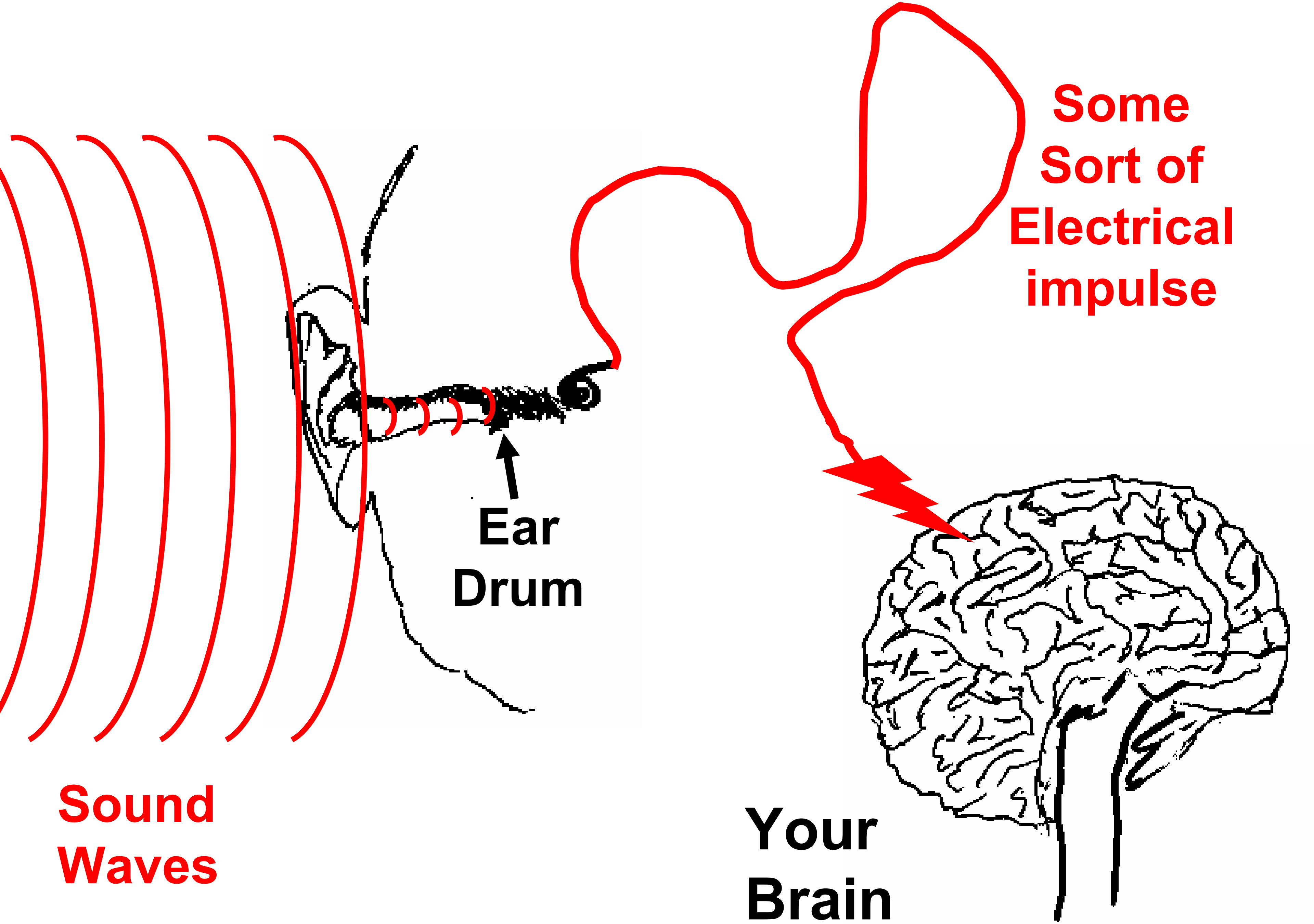
How far away are stars? How big are stars?



Both objects have an <u>angular diameter</u> of 3°


Run 94 Col 3 Field 387

They have different apparent brightness
They have different colors
They move
They change in brightness


Some
Sort of
Electrical
impulse
Ear
Drum
Sound
Waves
Your
Brain

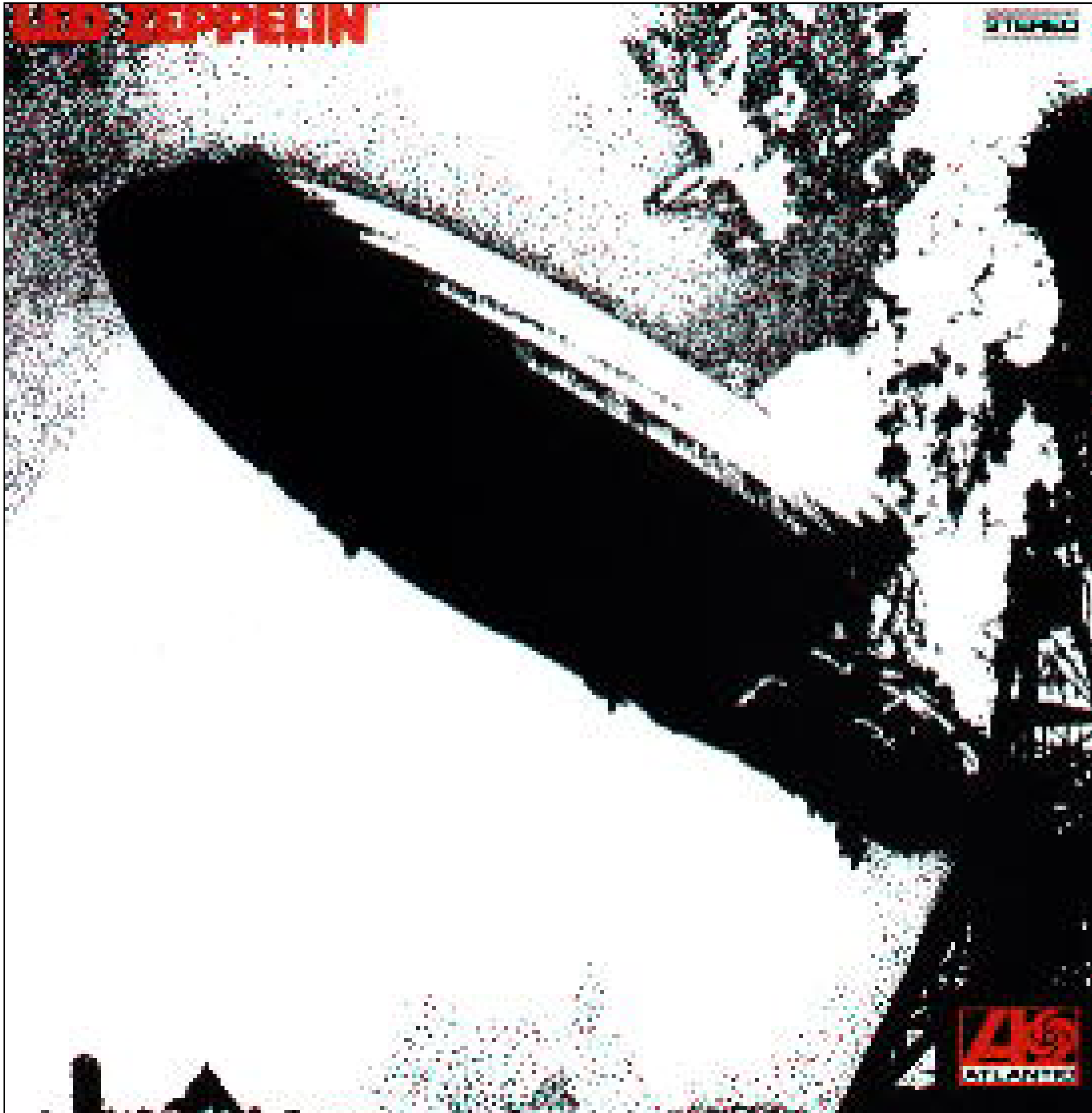
Loudness: Intensity: energy per second in ear

$I_{THRESHOLD}$ = energy per second in ear at threshold of hearing

I_{PAIN} = energy per second in ear at threshold of pain

$I_{PAIN} / I_{THRESHOLD}$ = ?

LED ZEPPELIN



Loudness: Intensity: energy per second in ear

$I_{THRESHOLD}$ = energy per second in ear at threshold of hearing

I_{PAIN} = energy per second in ear at threshold of pain

$I_{PAIN} / I_{THRESHOLD}$ = 10^{12} !!!

1 – 100 (10^2)

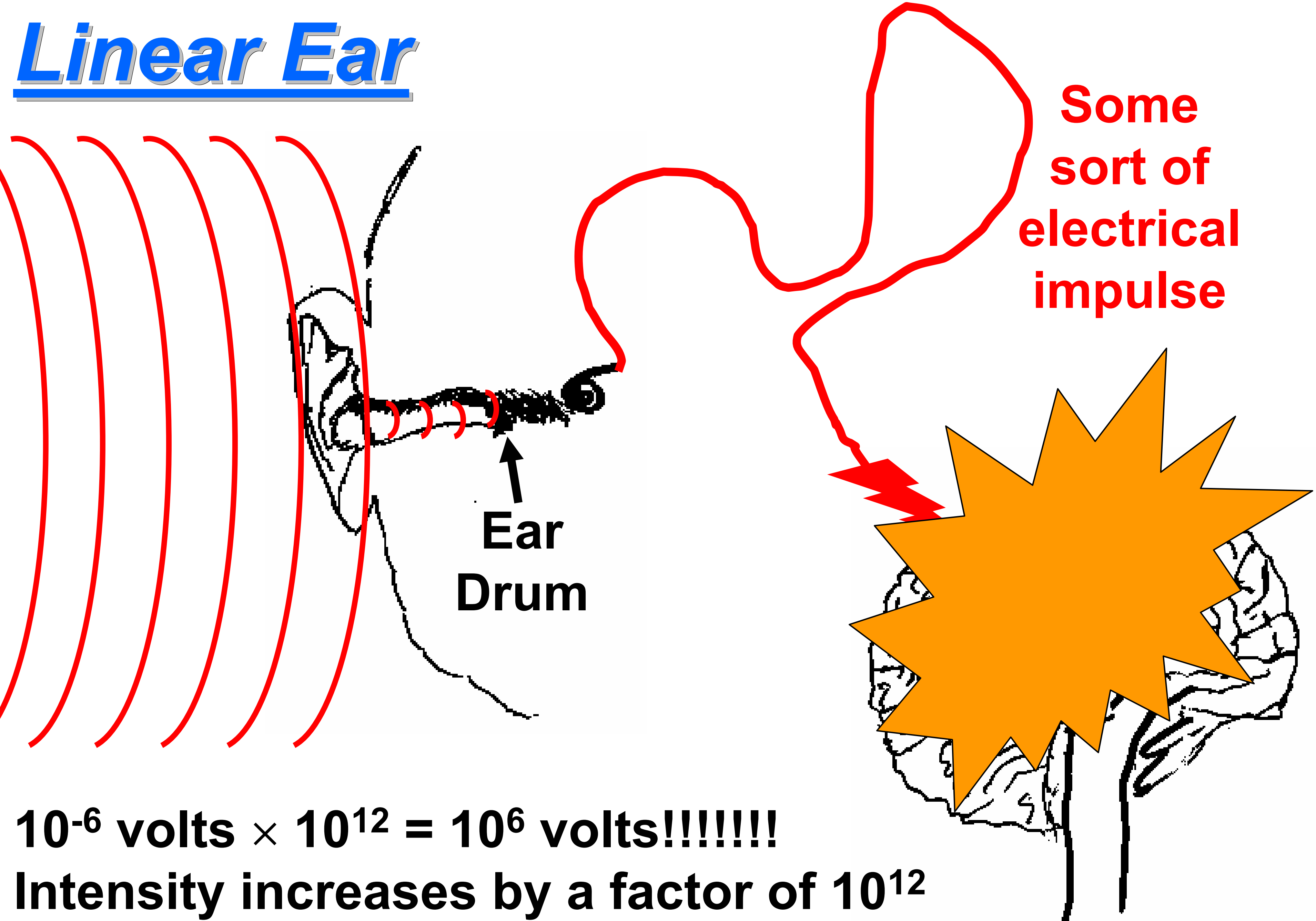
100 – 1,000 (10^3)

1,000 – 1,000,000 (10^6)

1,000,000 – 1,000,000,000 (10^9)

1,000,000,000 – 1,000,000,000,000 (10^{12})

Linear Ear



10^{-6} volts $\times$ 10^{12} = 10^{6} volts!!!!!!!

Intensity increases by a factor of 10^{12}

$\rightarrow$ electrical impulse increases by 10^{12}

Intensity: energy per time per area

$$I = \frac{\text{Energy}}{\text{Time Area}}$$

I_0 = threshold of hearing

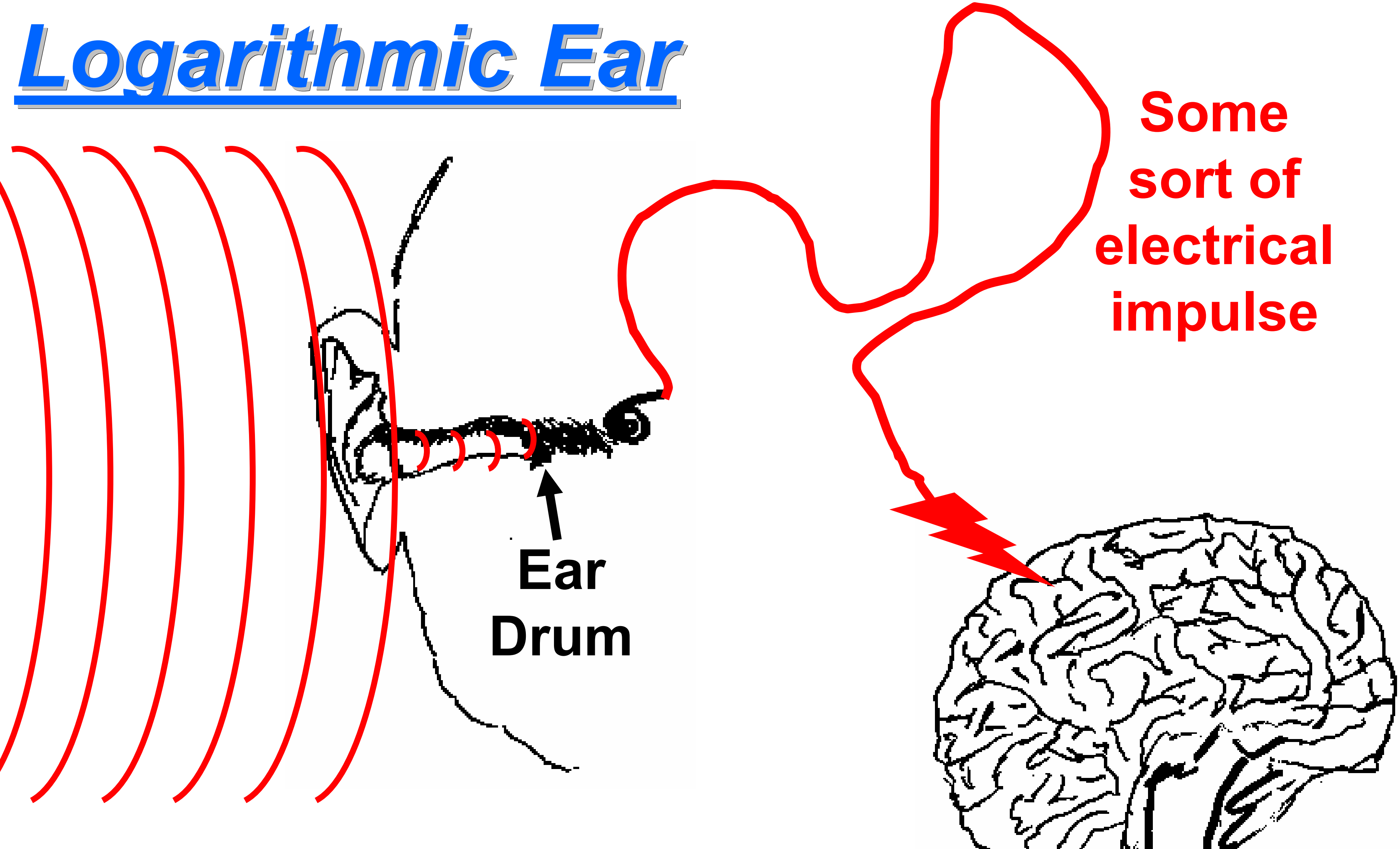
$$dB = 10 \log (I/ I_0)$$

$$I/ I_0 = 10^{12}$$

$$\log (10^{12}) = 12$$

$$dB = 10 \times 12 = 120$$

Logarithmic Ear



10^{-6} volts $\times$ 10 log(10^{12}) = 1.2 $\times 10^{-4}$ volts

Electrical impulse (output) only increases as the logarithm of the input

I_0 is intensity at threshold of hearing

I/I_0	$\log (I/ I_0)$	$dB = 10 \log (I/ I_0)$
10^{-2}	-2	-20
1	0	0
10^{2}	2	20
10^{6}	6	60
10^{12}	12	120
10^{20}	20	200

Difference of about 1 dB is about the smallest change that can be noticed by the human ear

$$\mathrm{dB}_1 = 10\log\left(I_1/I_0\right) \qquad \mathrm{dB}_2 = 10\log\left(I_2/I_0\right)$$

$$\mathrm{dB}_1 - \mathrm{dB}_2 = 10\log\left(I_1/I_0\right) - 10\log\left(I_2/I_0\right)$$

$$= 10\left[\log\left(I_1/I_0\right) - \log\left(I_2/I_0\right)\right]$$

$$= 10\left[\log\left(I_1\right) - \cancel{\log\left(I_0\right)} - \log\left(I_2\right) + \cancel{\log\left(I_0\right)}\right]$$

$$= 10\left[\log\left(I_1\right) - \log\left(I_2\right)\right] = 10\log\left(I_1/I_2\right)$$

$$1 = 10\log\left(I_1/I_2\right)$$

$$0.1 = \log\left(I_1/I_2\right) \rightarrow 10^{0.1} = I_1/I_2 \rightarrow 1.25 = I_1/I_2$$

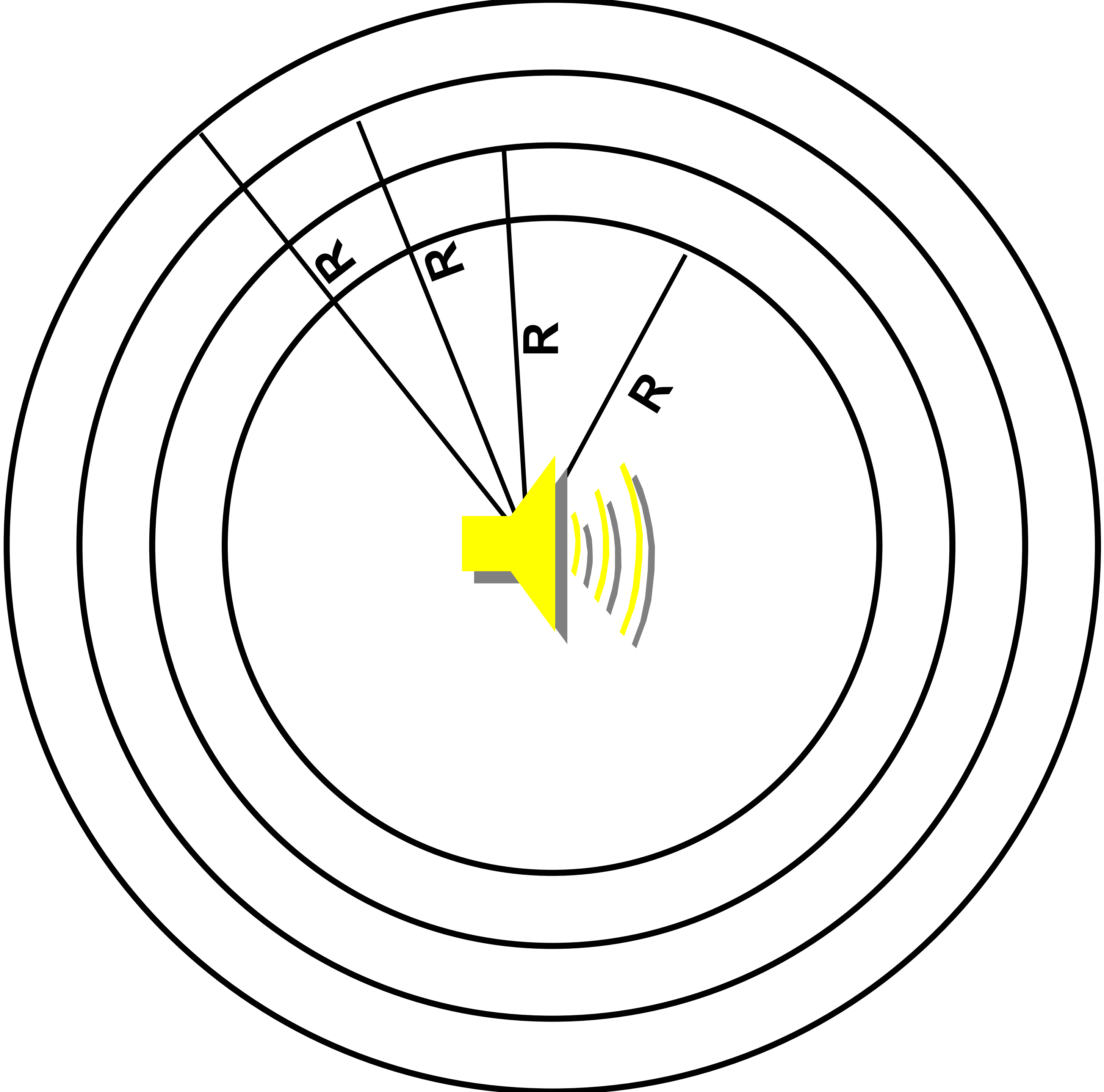
Intensity: energy per time per area

$$I = \frac{\text{Energy}}{\text{Time Area}}$$

$\frac{\text{Energy}}{\text{Time}}$ (Power) measured in watts

Area measured in cm^2

Intensity in watts per cm^2


R
R
R
R

Intensity: energy per time per area

$$I = \frac{\text{power}}{\text{cm}^2}$$

Power property of source

Intensity depends on power and distance between source and detector

$$\text{Intensity} = \frac{\text{power}}{4\pi R^2}$$

Let there be light

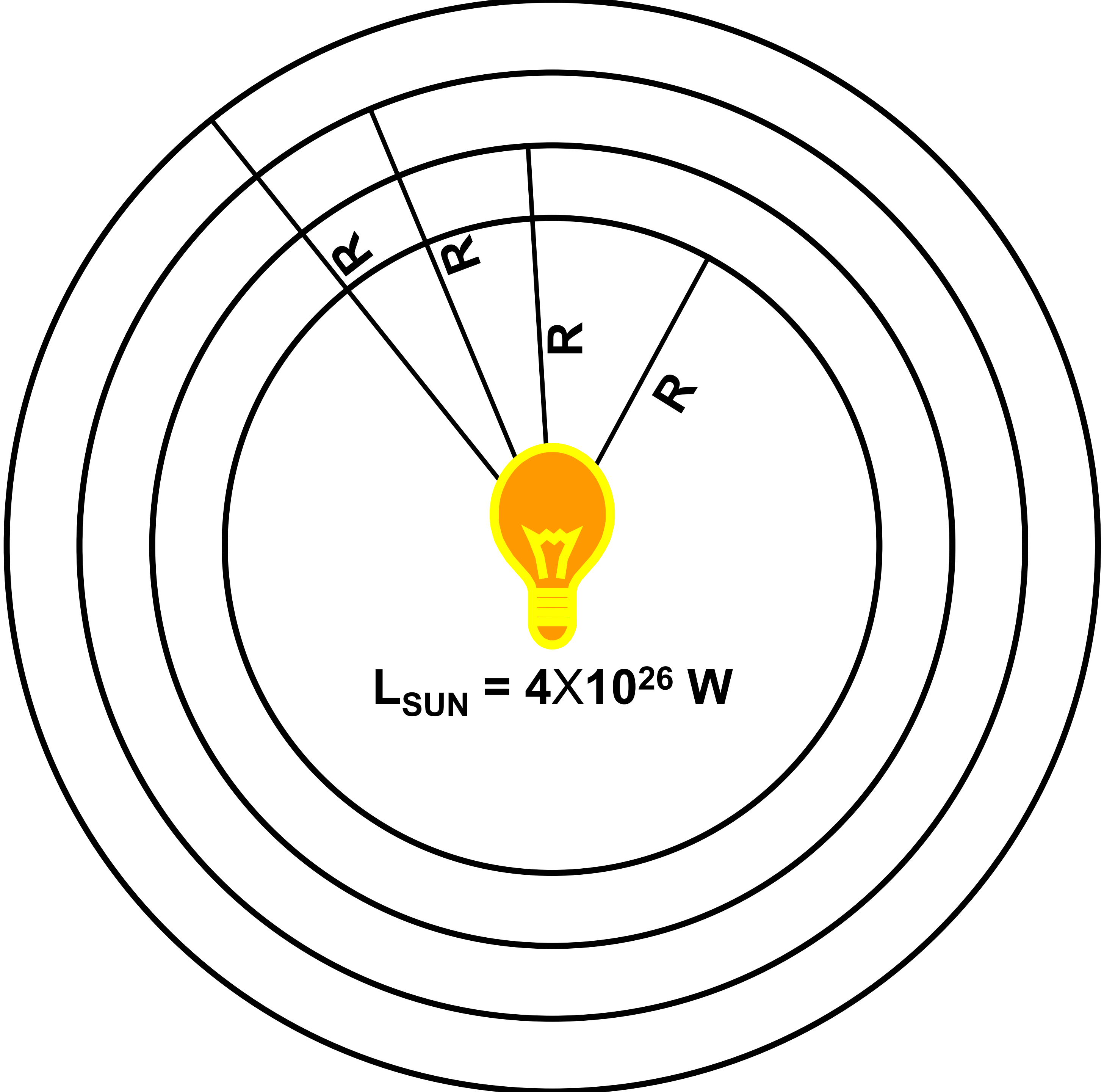
For light!!!

$$I = \frac{\text{Energy}}{\text{Time Area}}$$

$\frac{\text{Energy}}{\text{Time}}$ (Luminosity) measured in watts

Area measured in cm^2

Intensity in watts per cm^2


R
R
R
R
$L_{SUN} = 4 \times 10^{26}$ W

For light!!!

$$I = \frac{\text{luminosity}}{\text{cm}^2}$$

Luminosity property of source

Intensity depends on power and distance between source and detector

$$\text{Intensity} = \frac{\text{luminosity}}{4\pi R^2}$$

Logarithmic Eye